

5.0 EVALUATION OF GROUND WATER INVESTIGATION RESULTS

1. This chapter provides an evaluation of the limits of ground water impacts, natural attenuation evaluation, potential impacts on human and environmental receptors and an evaluation of the completeness of the GWRFI.

5.1 LIMITS OF GROUND WATER IMPACTS

1. The following sections provide an evaluation and summary of the historical and current limits of ground water impacts for VOCs, TPH and metals at the former ILM facility and the western portion of the BRC property.

5.1.1 VOCs

1. As indicated in Section 4.2.3.3.1, 10 VOCs were detected above their PQLs in the 13 onsite wells sampled in July 1999. TCE was the most frequently detected VOC; detected in 13 of the 14 samples (including one field duplicate) analyzed. A total of 12 VOCs were detected above their PQLs in the eight offsite BRC property wells sampled in July 1999. TCE was again the most frequently detected VOC.
2. TCE was highest in concentration, with PCE the second highest in both onsite and offsite wells. A discussion of the data trends relating to TCE and PCE (the most frequent and highest detected VOCs) is provided below. A summary of other VOCs detected is provided in Section 4.2.3.3.1.
3. In order to evaluate the limits of contamination over time, concentration contour maps for the major VOC constituents (TCE and PCE) were prepared. These plume maps are presented in Figures 5.1 through 5.6 and represent the concentration contours for TCE and PCE at three different points in time; December 1995, July 1997 and July 1999. These three points in time were selected because they represent the earliest and most recent site ground water data, along with an intermediate point, approximately equally spaced in time.
4. Contouring of the TCE analytical results for July 1999 (Figure 5.3) suggest seven isolated and/or merged plumes with concentrations greater than 1,000 µg/L. These plumes encompass existing or former wells as summarized below:
 - Well P-17 and abandoned Well P-25 (projected plume).

- Wells P-1, P-20, DAC-P1, BL-6 and abandoned Well P-15 (projected plume).
 - Well P-7, BL-3 and abandoned Well P-21 (projected plume).
 - Well P-22.
 - Damaged Well P-12 (projected plume).
 - Abandoned Well P-14 (projected plume).
 - Abandoned Well P-4 (projected plume).
5. Plumes projected around abandoned/damaged wells are based on historical data trends for those wells and surrounding wells. Plume configurations are based on a comparison of the TCE to PCE concentrations in each well, the TCE and PCE concentrations in up- and down-gradient wells near each plume and the ground water flow direction and gradient for the corresponding time frame. Data from other offsite wells (BRC property Wells DAC-P1, WCC-2S and WCC-10S) were also used to configure plumes. Data from wells screened in the deeper saturated zone (Wells P-16B and -16C) were not used for contouring.
6. The plume encompassing Well P-17 and abandoned Well P-25 was derived based on the historic and current TCE and PCE concentrations in these wells, with low to no detection of PCE in the surrounding wells. It appears that there was a separate local source contributing both TCE and PCE in this area, whereas other areas lacked the PCE constituent. The PCE, therefore, acts like a marker compound in defining the limits of the plume. The elevated presence and limited migration of PCE in Wells P-17 and abandoned Well P-25 also provides a basis and benchmark for assessing the lateral migration limits of ground water impacts in other areas.
7. The plume encompassing Wells P-1, P-20, DAC-P1, BL-6 and abandoned Well P-15 was derived based on the elevated TCE and hexavalent chromium concentrations with low to no detection of PCE; TCE, PCE and hexavalent chromium concentrations upgradient and downgradient in Wells BL-1, BL-5, P-25 (abandoned), P-6B, BL-2 and BL-7; and the direction of ground water flow. The northeasterly elongation of the plume in the direction of Well BL-6 may indicate that the historic direction of ground water flow (i.e., prior to the period of the water level data) was different than what is currently observed. Another mechanism for the northeasterly elongation is that the migration of the former release, which likely occurred in the area around Well P-1, was deflected by lower permeability strata in the vadose zone soil column (see Figure 3.4 and Boring Logs for Wells P-1, P-15, DAC-P1 and BL-6 in Appendix B). The eastern extent of the TCE plume beyond Well BL-6 is limited

based on the historical data from the BRC property Well WCC-2S (*Ground Water Monitoring Data Summary Report First Quarter 1997*, McDonnell Douglas Realty Company C-6 Facility, Torrance, California by Kennedy/Jenks Consultants, June 1997 [Kennedy/Jenks, 1997]).

8. The plume encompassing Wells P-7, BL-3 and abandoned Well P-21 was derived based on the historic and current TCE and PCE concentrations in these and surrounding wells and the inferred ground water flow direction and gradient.
9. The three plumes encompassing Wells P-22, P-12, P-4 and P-14 were derived based on the historic and current TCE and PCE concentrations in these and surrounding wells, and the ground water flow direction and gradient.
10. Plumes shown encompassing Well P-16A and abandoned Wells P-8, P-9 and P-19 in December 1995 (Figure 5.1) and July 1997 (Figure 5.2) are not indicated around these wells in July 1999 (Figure 5.3) based on July 1999 analytical data as well as historical data trends.
11. As shown in the figures, the data indicate that the plumes are becoming smaller and the elevated TCE concentrations have decreased significantly. TCE concentration trend plots are provided in Appendix I, and indicate decreases in TCE concentrations ranging from 33 to 96 percent in the most highly impacted wells at the former ILM facility, with the exception of Wells P-20 and P-22 in which TCE concentrations have remained relatively constant. Most of the decrease in TCE concentrations has occurred since 1996, after soil remediation activities at the former ILM facility were completed. In addition, due to the relatively flat gradient and low ground water velocity at the site, the plumes do not appear to be migrating downgradient from the former release areas.
12. In addition to a slow lateral rate of ground water movement and contaminant migration, the hydrologic and historic VOC concentration data indicate that the vertical gradient between the upper and lower ground water within the shallow water bearing zone at the site, defined as being within the Bellflower aquiclude, is minimal. Based on the March and July 1999 water elevations in Wells P-16A and P-16C and the difference in the bottom depth of Wells P-16A and P-16C (32 ft), the potential downward vertical gradient is estimated at 0.003 to 0.004 ft/ft. The historical VOC data from Wells P-16A and P-16C also indicates slow vertical contaminant migration. The TCE concentrations detected in Well P-16C from mid-1996 to mid-1997 (e.g., 340 to 440 µg/L) have been an order of magnitude less than the TCE concentration in Well P-16A (e.g., 3,400 to 4,100 µg/L). Currently, the TCE concentration in Well P-16A has

decreased (e.g., 530 µg/L) and is similar to the concentration in Well P-16C (e.g., 440 µg/L), indicating low downward vertical migration. This data is consistent with the fact that the vertical migration of the impacted ground water is limited by the presence of the lower Bellflower aquiclude below the bottom of Well P-16C.

13. Contouring of the PCE analytical results suggest one plume encompassing Well P-17 and abandoned Well P-25 (Figures 5.4 through 5.6). Evaluation of the PCE plume over time indicates that the plume is becoming smaller and the elevated PCE concentrations have decreased significantly. The 1,000 µg/L PCE contour is no longer indicated around these wells in the July 1999 data (Figure 5.6). PCE concentration trend plots are provided in Appendix I and indicate decreases in PCE concentrations from 67 to 74 percent. Again, most of the decrease in PCE concentrations has occurred since 1996, after soil remediation activities were completed. Due to the relatively flat gradient and low ground water velocity at the site, the plume does not appear to be migrating downgradient from the former release area.
14. Other than 1,1-DCE in Well P-17 and abandoned Well P-25, the concentrations of other VOCs in the former ILM facility and BRC property wells have generally been significantly below 100 µg/L and, in most wells, below detection limits. The 1,1-DCE concentrations have also decreased significantly in Well P-17 and abandoned Well P-25 over time (see concentration trend plots in Appendix I and Table 4.6). As discussed later in Section 5.2, the presence of low concentrations of di- and mono-chlorinated aliphatic hydrocarbons is likely the result of some natural degradation of the more highly chlorinated compounds (e.g., TCE and PCE). Other than the noted presence and low concentration levels of these other VOCs, concentration contour maps do not appear to be meaningful and were not prepared.

5.1.2 TOTAL PETROLEUM HYDROCARBONS

1. As indicated in Section 4.2.3.3.2, TPHs at the TPH-d hydrocarbon and heavier range were detected in four onsite wells (P-2 [crude/waste oil and TPH-d ranges], P-9B [crude/waste oil range], P-16C [crude/waste oil range] and P-24 [crude/waste oil range]) and two offsite BRC property wells (BL-1 [TPH-d range] and BL-5 [TPH-d range]) sampled in July 1999. Former ILM facility Well P-5 was not sampled in July 1999 due to a hydrocarbon sheen encountered during water-level measurement activities.

2. Historical TPH detections in former ILM facility wells have been sporadic with little discernable trends, with the exception of crude/waste oil and TPH-k results in Well P-2 and TPH-d results in Well P-5. TPH concentrations in Wells P-2 and P-5 have decreased significantly over time. The analytical results for Wells P-2 and P-5 in Table 4.8 indicate decreases in TPH concentrations from 67 to 90 percent. Again, most of the decrease in TPH concentrations has occurred after soil remediation activities were completed in 1996.
3. The highest hydrocarbon result from historical data was 60,000 µg/L for TPH-k in Well P-2 in December of 1995. The highest hydrocarbon result for the July 1999 sampling event was 1,800 µg/L for TPH (crude/waste oil) in Well P-2. The presence of TPH in former ILM facility wells, such as Well P-2, may be attributed to previous onsite releases as well as offsite releases such as the Mobil Oil Refinery located west of the site. The presence of TPHs in Well P-5 and possibly BRC property Wells BL-1 and BL-2 appears to be from former onsite releases around the Well P-5 area.
4. Remediation goals for TPHs in ground water are established on a site by site basis in California. The remediation goals are typically health based and focus on the hazardous TPH constituents such as BTEXs. Due to the lack of such constituents in the TPHs detected in the former ILM facility and BRC property wells, ground water remediation goals will likely not include dissolved TPHs.
5. Other than the noted presence and low concentration levels of these TPHs, concentration contour maps do not appear meaningful and were not prepared. These low concentration levels also do not represent a significant environmental concern.

5.1.3 METALS

1. As indicated in Section 4.2.3.3.3, 15 total and 8 dissolved metals were detected in the onsite wells, and 16 total and 5 dissolved metals were detected in the offsite BRC property wells. Of the metals, only two exceeded MCL levels in the most recent sampling. Dissolved total and hexavalent chromium exceeded the primary MCL of 50 µg/L in Wells P-1 and BL-6 (approximately 1,000 µg/L and 200 µg/L, respectively). As noted previously, the total chromium is present primarily as hexavalent chromium. Dissolved manganese exceeded the secondary MCL of 50 µg/L in Wells P-2, P-6B, P-7 and P-24 (approximately 1,400 µg/L, 800 µg/L, 300 µg/L and 100 µg/L, respectively).

2. A comparison of historical dissolved ground water results with typical natural concentrations (Dragun, 1988) indicates detected metals are within normal ranges with the exception of chromium as shown in Table 5.1. Additional data on natural concentrations of metals in soil and ground water is included in Appendix J.
3. Ground water plumes for dissolved hexavalent chromium for the December 1995, July 1997 and July 1999 time periods were prepared and are presented in Figures 5.7, 5.8 and 5.9. Contouring of the dissolved hexavalent chromium results for July 1999 (Figure 5.9) suggest two isolated plumes greater than 100 µg/L encompassing existing or former wells:
 - Wells P-1, DAC-P1, BL-6 and abandoned Well P-15 (projected plume).
 - Abandoned Well P-14 (projected plume).
4. Plumes projected around abandoned wells are based on historical data trends from the abandoned and surrounding wells. Plume configurations are based on comparison of dissolved hexavalent chromium in each well, in nearby up-gradient and down-gradient wells, and the ground water flow direction and gradient.
5. The July 1999 dissolved hexavalent chromium plume encompassing Wells P-1, DAC-P1, BL-6 and abandoned Well P-15, shown in Figure 5.9, correlates with the July 1999 TCE plume shown in Figure 5.3 and possibly indicates a common former release point around the Well P-1 area. As with the TCE plume, the northeasterly elongation of the plume in the direction of Well BL-6 may be the result of historic ground water flow directional changes across the site and/or deflection of the downward migration of the former release due to lower permeability strata in the vadose zone in the release area.
6. Evaluation of the dissolved hexavalent chromium plumes over time indicate that the plumes are becoming smaller and elevated hexavalent chromium concentrations have decreased significantly. In addition, data trends over time indicate hexavalent chromium plumes of 100 µg/L or greater are no longer present around Well P-17 and abandoned Wells P-25 and P-4. Chromium trend plots are provided in Appendix H and indicate decreases in dissolved hexavalent chromium concentrations from 79 to 97 percent, with the exception of Well P-1 in which concentrations have remained relatively constant. Again, most of the decrease in hexavalent chromium concentrations has occurred after soil remediation activities were completed in 1996.

5.2 EVALUATION OF POTENTIAL FOR NATURAL ATTENUATION OF CHLORINATED HYDROCARBONS

1. Natural attenuation of chlorinated hydrocarbons by degradation in ground water can occur through microbial/biological or chemical processes or both. Current literature, laboratory and field data indicate that the most commonly found products of microbial degradation of these compounds come from reductive dehalogenation (i.e., the replacement of the halogen by hydrogen) under anaerobic conditions, while nonmicrobial degradations tend to involve hydrolysis and/or oxidation, (*Degradation of Volatile Chlorinated Aliphatic Priority Pollutants in Ground Water*, September 15, 1984, Smith, L.R. and Dragun, J., Environmental International, Vol. 10, pp. 291-298 [Smith and Dragun, 1984]). The following sections summarize both microbial and chemical processes that are most prevalent. These processes (pathways) along with reaction/degradation products and half-lives for several typical chlorinated hydrocarbons are also summarized in Table 5.2. The important natural attenuation parameters are also summarized below along with a screening evaluation for the potential for natural attenuation using the U.S. EPA *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water*, September 1998 (USEPA, 1998).

5.2.1 IMPORTANT NATURAL ATTENUATION PROCESSES OF CHLORINATED HYDROCARBONS

5.2.1.1 Microbial Attenuation Processes

5.2.1.1.1 Reduction Dehalogenation/Electron Acceptor Reactions

1. The most important process for the natural biodegradation of the more highly chlorinated solvents is reductive dechlorination. During this process, the chlorinated hydrocarbon is used as an electron acceptor, not as a source of carbon, and a chlorine atom is removed and replaced with a hydrogen atom. In general, reductive dechlorination occurs by sequential dechlorination from PCE to TCE to DCE to vinyl chloride to ethene. Depending upon environmental conditions, this sequence may be interrupted with other processes which then act upon the products. During reductive dechlorination, all three isomers of DCE can theoretically be produced. However, under the influence of biodegradation, cis-1,1-DCE is a more common intermediate than trans-1,2-DCE, and 1,1-DCE is the least prevalent of the three DCE isomers. Reductive dechlorination of chlorinated solvent compounds is associated with the accumulation of daughter products (i.e., similar compounds containing fewer chlorine atoms) and an increase in the concentration of chloride ions.
2. Reductive dechlorination affects each of the chlorinated ethenes differently. Of these compounds, PCE is the most susceptible to reductive dechlorination because it is the most

oxidized. Conversely, vinyl chloride is the least susceptible to reductive dechlorination because it is the least oxidized of these three compounds. As a result, the rate of reductive dechlorination decreases as the degree of chlorination decreases. This rate decrease may explain the accumulation of vinyl chloride in PCE and TCE plumes that are undergoing reductive dechlorination.

3. Reductive dechlorination has been demonstrated under nitrate- and iron-reducing conditions, but the most rapid biodegradation rates, affecting the widest range of chlorinated aliphatic hydrocarbons, occur under sulfate-reducing and methanogenic conditions.
4. Because chlorinated aliphatic hydrocarbon compounds are used as electron acceptors during reductive dechlorination, there must be an appropriate source of carbon for microbial growth in order for this process to occur. Potential carbon sources include natural organic matter, fuel hydrocarbons, or other anthropogenic (resulting from the influence of human beings on nature) organic compounds (USEPA, 1998).

5.2.1.1.2 Electron Donor Reactions

1. Microorganisms are generally believed to be incapable of growth using PCE and TCE as a primary substrate (i.e., electron donor). However, under aerobic and some anaerobic conditions, the less oxidized chlorinated aliphatic hydrocarbons (e.g., vinyl chloride) can be used as the primary substrate in biologically mediated oxidation-reduction reactions. In this type of reaction, the facilitating microorganism obtains energy and organic carbon from the degraded chlorinated aliphatic hydrocarbon.
2. In contrast to reactions in which the chlorinated aliphatic hydrocarbon is used as an electron acceptor, only the least oxidized chlorinated aliphatic hydrocarbons can be used as electron donors in biologically mediated oxidation-reduction reactions. Investigations have shown that vinyl chloride and 1,2-DCA were shown to serve as primary substrates under aerobic conditions and that dichloromethane has the potential to function as the primary substrate under either aerobic or anaerobic environments. In addition, evidence of mineralization of vinyl chloride under iron-reducing conditions exists so long as there is sufficient bioavailable trivalent iron (iron [III]).

3. Aerobic metabolism of vinyl chloride may be characterized by a loss of vinyl chloride mass and a decreasing molar ratio of vinyl chloride to other chlorinated aliphatic hydrocarbon compounds. In addition, mineralization of DCE to carbon dioxide can exist under aerobic, Fe(III) reducing, and methanogenic conditions, respectively (USEPA, 1998).

5.2.1.1.3 Cometabolism

1. When a chlorinated aliphatic hydrocarbon is biodegraded via cometabolism, the degradation is catalyzed by an enzyme or cofactor that is fortuitously produced by the organisms for other purposes. The organism receives no known benefit from the degradation of the chlorinated aliphatic hydrocarbon. Rather, the cometabolic degradation of the chlorinated aliphatic hydrocarbon may in fact be harmful to the microorganism responsible for the production of the enzyme or cofactor.
2. Cometabolism is best documented in aerobic environments, although it potentially could occur under anaerobic conditions. It has been reported that under aerobic conditions chlorinated ethenes, with the exception of PCE, are susceptible to cometabolic degradation. Further evidence suggests that the rate of cometabolism increases as the degree of dechlorination decreases.
3. During cometabolism, the chlorinated alkene is indirectly transformed by bacteria as they use anthropogenic carbon or another substrate to meet their energy requirements. Therefore, the chlorinated alkene does not enhance the degradation of anthropogenic carbon or natural carbon sources, nor will its cometabolism interfere with the use of electron acceptors involved in the oxidation of those carbon sources (USEPA, 1998).

5.2.1.2 Chemical (Abiotic) Attenuation Processes

5.2.1.2.1 Hydrolysis and Oxidation

1. In the absence of microbial action and barring such processes as volatilization or light-induced reactions, the most commonly observed chemical reaction pathway for chlorinated aliphatic hydrocarbons in water has been slow hydrolysis, at times accompanied by oxidation. In such reactions, the products are usually chlorinated alcohols and/or carboxylic acids, which are water soluble and thus difficult to detect at trace levels (Smith and Dragun, 1984).

2. Hydrolysis is defined as a chemical reaction in which a chemical reacts with water or a hydroxide ion (OH^-). A nucleophile (water or OH^-) attacks an electrophile (compound involving or having an affinity for electrons) and displaces a leaving group (i.e., ion). During these reactions, a carbon-leaving group bond is cleaved (broken) and a carbon-oxygen bond is formed. Hydrolysis reactions are generally classified as nucleophilic displacement/substitution reactions (Dragun, 1988).
3. Unlike hydrolysis and other substitution reactions, oxidations and accompanying reductions require external electron acceptors and donors, respectively. Generally, organic compounds acting as electron donors undergo oxidation reactions. However, because of the electronegative character of halogen atoms on aliphatic compounds, polyhalogenated aliphatic compounds often behave as electronic acceptors or oxidants and are reduced in the process. Thus, halogenated aliphatic compounds may be either oxidized or reduced, depending on their structure and environmental conditions. The least halogenated compounds (i.e., vinyl chloride, chloroethane) are more susceptible to oxidation versus the highly halogenated compounds. In most reactions described to date, the electron acceptors and donors used to oxidize and reduce halogenated aliphatic compounds are derived from biological systems, *Transformation of Halogenated Aliphatic Compounds*, ES&T Critical Review, 1987 (Vogel, Criddle, McCarty, 1987).
4. Because hydrolysis and oxidation products are quite water soluble, they tend to be more reactive than the halocarbon from which they are derived. This results in transitory, difficult-to-detect intermediates. In contrast, chlorinated reduction products retain solubility and reactivity characteristics that are rather similar to those of the starting chlorinated hydrocarbons. Although the greater volatility of reduction products may result in slightly increased difficulty of analysis, they are still much more easily detected at trace concentrations than are the polar compounds formed by oxidation or hydrolysis.
5. Tracer studies have made it possible to show that common end results of degradative metabolism, oxidation, and hydrolysis, are incorporation into cell material and production of carbon dioxide or carbonate (Smith and Dragun, 1984).

5.2.2 NATURAL ATTENUATION PARAMETERS OF IMPORTANCE

5.2.2.1 Ground Water Quality Parameters

1. As indicated in Section 4.2.3.3.4, ground water quality parameters collected by field measurements included specific conductivity, redox potential, pH, and temperature. Ground water quality parameters collected for laboratory analysis included alkalinity, ammonia nitrogen, dissolved organic carbon and ortho-phosphate.
2. Knowledge of the redox potential of ground water is important since the redox potential of a ground water system influences the rates of biodegradation and because some biological processes operate only within a prescribed range of redox potential conditions. A summary of the redox potentials for various oxidation-reduction reactions is provided below:
 - Aerobic Respiration +820 mV
 - Anaerobic Respiration - Denitrification: +740 mV
 - Anaerobic Respiration - Iron Reduction: -50 mV
 - Anaerobic Respiration - Sulfate Reduction: -222 mV
 - Anaerobic Respiration - Methanogenesis: -240 mV

Reductive dechlorination occurs under reducing (anaerobic) conditions. The general redox potential range for reductive dechlorination is -310 to +750 mV with the optimal range at -400 to -135 mV.

3. Denitrification occurs when nitrate is converted primarily to nitrogen gas under reducing conditions. Organic matter will decay to ammonia under reducing conditions. If the receiving ground water is reducing, the nitrogen will stay in the ammonia form. If it is oxidizing, bacteria will convert the ammonia to nitrite and then to nitrate. Nitrite is a very reactive ion and is almost immediately converted to nitrate, so that little nitrite is normally found in the environment.
4. Iron reduction anaerobic respiration is the process in which iron (III) (Fe^{+3}) is used as an electron acceptor during anaerobic biodegradation of organic carbon. During this process, iron (III) is reduced to iron (II) (Fe^{+2}), which may be soluble in water. Iron (II) concentrations can thus be used as an indicator of anaerobic degradation of fuel compounds and vinyl chloride. Native organic matter may also support further reduction of iron (II). Care must be taken when interpreting iron (II) concentrations because they may be biased low by reprecipitation as sulfides or carbonates.

5. Knowledge of the DOC content of the aquifer also is important for sorption and solute-retardation calculations (i.e., containment adsorption and dispersion). The dissolved phase is available for bacteria and is released back as carbon dioxide through cellular respiration. Knowledge of the ortho-phosphate content is important since bacteria decompose the complex phosphorus into available ortho-phosphate.

5.2.2.2 Terminal Electron Acceptor Parameters

1. As indicated in Section 4.2.3.3.4, terminal electron acceptor parameters included dissolved oxygen, nitrite/nitrate, total and dissolved iron, total and dissolved manganese, sulfate, hydrogen sulfide, carbon dioxide and methane.
2. Dissolved oxygen is the most thermodynamically favored electron acceptor used by microbes for the biodegradation of organic carbon, whether natural or anthropogenic. Anaerobic bacteria generally cannot function at dissolved oxygen concentrations greater than about 0.5 mg/L and, hence, reductive dechlorination (Section 5.4.1) will not occur. This is why it is important to have a source of carbon in the aquifer that can be used by anaerobic microorganisms as a primary substrate. During aerobic respiration, dissolved oxygen concentrations decrease. After depletion of dissolved oxygen, anaerobic microbes will use nitrate as an electron acceptor, followed by iron (III), then sulfate, and finally carbon dioxide (methanogenesis [methane generation]). Each sequential reaction drives the redox potential of the ground water downward into the range within which reductive dechlorination can occur. Reductive dechlorination is most effective in the redox potential range corresponding to sulfate reduction and methanogenesis, but dechlorination of PCE and TCE also may occur in the redox potential range associated with denitrification or iron (III) reduction. Dehalogenation of DCE and volatile compounds generally are restricted to sulfate reducing and methanogenic conditions.
3. After dissolved oxygen has been depleted in the microbiological treatment zone, nitrate may be used as an electron acceptor for anaerobic biodegradation of organic carbon via denitrification. In order for reductive dechlorination to occur, nitrate concentrations in the contaminated portion of the aquifer must be less than 1.0 mg/L.
4. Manganese is also an electron acceptor but less abundant if anaerobic biological activity is solubilizing manganese from the aquifer matrix material.

5. After dissolved oxygen and nitrate have been depleted in the microbiological treatment zone, sulfate may be used as an electron acceptor for anaerobic biodegradation. This process is termed "sulfate reduction" and results in the production of sulfide. Concentrations of sulfate greater than 20 mg/L may cause competitive exclusion of dechlorination. However, in many plumes with high concentrations of sulfate, reductive dechlorination still occurs.
6. Carbon dioxide is a primary byproduct of biodegradation of organic carbon under aerobic conditions, and can be an indicator as previously mentioned in this section of the report with the dissolved organic carbon and dissolved oxygen discussion.
7. Methane is a primary by-product of the biodegradation of organic carbon under anaerobic conditions. During methanogenesis, the organic carbon compound acetyl group is split to form carbon dioxide and methane, or carbon dioxide is used as an electron acceptor, and is reduced to methane. Methanogenesis generally occurs after oxygen, nitrate, and sulfate have been depleted in the treatment zone. The presence of methane in ground water is indicative of strongly reducing conditions. Because methane is not present in most hydrocarbon releases, the presence of methane above background concentrations in ground water in contact with hydrocarbon contaminants is indicative of microbial degradation of hydrocarbons. Methane also is associated with plumes of chlorinated solvents in ground water. It is not known if the methane comes from chlorinated solvent carbon or from native dissolved organic carbon.

5.2.2.3 Degradation Product Parameters

1. As indicated in Section 4.2.3.3.4, degradation product parameters included chloride, ethane and ethene.
2. During biodegradation, hydrolysis, and/or dehydrohalogenation of chlorinated hydrocarbons dissolved in ground water, chloride is released. This results in chloride concentrations in ground water in the contaminant plume that are elevated relative to background concentrations. Because of the neutral chemical behavior of chloride, it can be used as a conservative tracer to estimate biodegradation rates. In addition, ethane and ethene are the by-products of the degradation of halogenated ethane and ethene compounds. The presence of ethane and ethene, therefore, indicate biodegradation is taking place.

5.2.3 NATURAL ATTENUATION ANALYSIS

1. A screening analysis for natural attenuation by biological and chemical degradation was performed on the ground water data collected at the former ILM facility site and adjacent BRC property using the EPA protocol for evaluating natural attenuation (USEPA, 1998). The natural attenuation analysis involved a comparison of the chlorinated hydrocarbon and natural attenuation parameter results for wells most impacted by chlorinated hydrocarbons with those for wells which were upgradient, crossgradient and downgradient and which had low or nondetect chlorinated hydrocarbons. This comparison is summarized in Table 5.3. A screening analysis scoring summary for potential natural attenuation by anaerobic biodegradation, performed using the procedures in the EPA protocol, is presented in Table 5.4.
2. The comparison of the natural attenuation parameters indicates only minimal differences between the impacted and non-detect or "background" wells. The only data trends observed were slightly lower redox potential and slightly higher dissolved manganese results in the non-detect or background wells versus the impacted wells. Based on a review of the natural attenuation parameter results, it appears only minimal natural microbial/biological degradation of the chlorinated hydrocarbons is taking place in impacted shallow ground water below the site. The screening analysis scoring for the potential natural attenuation by anaerobic biodegradation was "-2" which indicates "inadequate evidence for anaerobic biodegradation of chlorinated hydrocarbons" according to the EPA guidance protocol (USEPA, 1998).
3. However, since the source areas of contamination in the soils have been remediated at the site, the data trends suggest that other natural attenuation processes in the shallow ground water such as chemical and more likely physical processes (e.g., dispersion/ diffusion and advective flow, etc.) have been effective in reducing the chlorinated hydrocarbon and hexavalent chromium concentrations and plumes. In addition, due to the estimated and demonstrated slow rate of ground water movement and flat gradient, the plumes have not migrated significantly downgradient or vertically downward in the water bearing zone.

5.3 POTENTIAL IMPACTS ON HUMAN AND ENVIRONMENTAL RECEPTORS

1. Human and environmental receptors are unlikely to be exposed to constituents of potential concern (COPCs) (e.g., VOCs, metals, etc.) in ground water under either current or potential future conditions. The exposure assessment process includes three primary steps: (1) Characterize the Exposure Setting; (2) Identify Exposure Pathways; and (3) Quantify Exposure. The quantification of exposure will be conducted as a component of the ground water risk assessment that will be submitted as a separate document to the DTSC and will be based on the potentially hypothetical exposed populations and exposure pathways identified in the following paragraphs.

5.3.1 CHARACTERIZATION OF EXPOSURE SETTING

1. The exposure setting consists of the general physical characteristics of the site and the characteristics of the populations on or near the site. For the purpose of this analysis, the exposure setting is separated spatially by potential onsite and offsite characteristics.
2. The former ILM facility is located within the City of Los Angeles and borders the City of Torrance. The property was historically zoned M3-1 (heavy industrial use) but is currently zoned M2 (light industrial use). The designation (M2), includes limited commercial and manufacturing uses, clinics, limited machine shops, animal hospitals and kennels, industrial uses, mortuaries, agriculture, storage yards of all kinds and animal keeping. Land zoned M2 cannot be used for residential dwellings of any kind, hospitals, schools or churches.
3. Within 1,000 feet of the former ILM facility, four zoning classifications are found within the City of Torrance and nine are identified within the City of Los Angeles. The zoning classifications consist primarily of industrial, commercial, and manufacturing zoning with limited areas of single-family residential and restricted-density multiple dwellings. The residentially zoned areas are located approximately 1,000 feet north and south of the site. The residential areas to the south are generally located downgradient of the former ILM facility. Designated parks, wildlife areas, preserves, reserves, sanctuaries, conservation areas, or other protected areas are not located within 1 mile of the site. Ground water discharge points such as streams, seeps, or springs also are not located within 1 mile of the site.

4. Based on the current and anticipated future land use considerations, the potential offsite receptor populations include offsite adult and child residents and offsite adult workers. Potential onsite receptors include adult workers. Ground water is not considered a significant medium of exposure for ecological receptors at the site or surrounding area, and will not be evaluated.

5.3.2 IDENTIFICATION OF POTENTIAL EXPOSURE PATHWAYS

1. Direct contact (ingestion and/or dermal contact) with COPCs in ground water and inhalation of COPCs resulting from ground water use by either onsite or potential offsite receptors can only occur after ground water has been extracted from the subsurface. The current known distribution of COPCs in ground water is generally limited to the onsite portion of the Bellflower aquiclude and those areas within 500 feet immediately adjacent to the site. Ground water from the Bellflower aquiclude is not currently utilized onsite or downgradient of the site within a 2-mile radius and this aquifer is not a production source for potable or industrial use. Given the industrial nature of the area and the poor quality and yield of ground water from the Bellflower aquiclude, it is unlikely that ground water from this zone will be used for either onsite or offsite industrial, domestic, or agricultural use. The likelihood of potential agricultural use of ground water is further limited due to the absence of agricultural property within a 2-mile radius of the site.
2. Because there are no current ground water extraction wells onsite, or likely to be in the future due to land use restrictions and poor quality and yield of ground water from the Bellflower aquiclude, potential exposures associated with ground water use by potential onsite receptors is an incomplete pathway and will not be evaluated quantitatively in the ground water risk assessment. However, if the COPCs are capable of migrating in dissolved-phase to a "hypothetical" offsite extraction point, this exposure pathway may be complete for potential offsite receptors. In order to evaluate the potential viability of this hypothetical exposure pathway, environmental fate and transport analysis of dissolved-phase chemical migration in ground water will be conducted as a component of the ground water risk assessment. The environmental fate and transport analysis will be used to qualitatively determine if migration of COPCs in ground water is plausible and to estimate the concentrations of COPCs at an, as yet, undetermined downgradient location. Identification of the fate and transport modeling approach and downgradient location will be determined through discussions with the DTSC.

3. Potential exposure pathways associated with the presence of volatile COPCs (e.g., VOCs) for both onsite and offsite receptors also include volatilization from ground water and diffusion of vapors into onsite and offsite structures. This exposure pathway represents a completed exposure pathway since commercial buildings are present onsite. This pathway may also be a complete exposure pathway for potential offsite receptors if offsite migration of dissolved-phase COPCs occurs. Although the magnitude of the exposure pathway is considered to be negligible, a quantitative evaluation of this pathway will be conducted as a component of ground water risk assessment.

5.3.3 SUMMARY OF POTENTIAL EXPOSURE PATHWAYS AND RECEPTORS

1. Potential complete exposure pathways exist for both onsite and offsite receptors. A summary of the potentially complete exposure pathways and receptor populations is provided below:

EXPOSURE SCENARIO	EXPOSURE ROUTE	POTENTIAL HUMAN RECEPTORS		
		Offsite		Onsite
		Adult	Child	Adult
Hypothetical Ground Water Use (domestic)	Inhalation	√	√	--
	Dermal Contact	√	√	--
	Ingestion	√	√	--
Volatilization from Ground Water	Inhalation	√	√	√

- √ Potentially complete exposure pathway.
 -- Not complete pathway.

5.3.4 QUANTIFICATION OF EXPOSURE

1. Exposure quantification will be performed to derive estimates of exposure to chemicals in ground water. The quantification of human exposure to COPCs will be conducted as a component of the ground water risk assessment. Standard exposure parameters published by the U.S. EPA 1999, *Exposure Factors Handbook*, Office of Research and Development, EPA 600/c-99-001 (USEPA, 1999) and the DTSC 1992, *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Site and Permitted Facilities*, Office of the Science Advisor, July (DTSC, 1992) are proposed to characterize exposure in the ground water risk assessment. Estimates of chemical doses and carcinogenic and noncarcinogenic risks will be estimated using U.S. EPA 1989, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Parts A, B, and C)*, Office of Emergency and Remedial Response, EPA 540/1-89-002 (USEPA, 1989b) and (DTSC, 1992) guidance documents.

2. At this time, there are no known historical or current impacts on human or environmental receptors from releases into the ground water identified in this GWRFI.

5.4 EVALUATION OF COMPLETENESS OF GWRFI

1. Pursuant to the Scope of Work for a RCRA Facility Investigation in Attachment D of the Corrective Action Consent Agreement, the following information has been included in this GWRFI:

- A summary of the site history and investigation activities.
- A summary of current site conditions (including an aerial photograph).
- A complete description of the investigation, including all data necessary to understand the project in its entirety including all investigative methods and procedures.
- A discussion of key decision points encountered and resolved during the course of the investigation.
- Graphical displays such as potentiometric surface maps, cross-sections, plume contour maps (showing concentration levels, isoconcentration contours), well concentration trend plots, facility maps (showing well locations, etc.) that describe report results. Highlights of important facts such as geologic features that may have affected contaminant transport have also been included.
- Tables that list all analytical data for each matrix investigated.
- An analysis of current and historical ground water data to illustrate temporal changes for both water chemistry and piezometric data (including piezometric surface contour maps and ground water elevation trend plots).
- A description of potential or known impacts on human and environmental receptors from releases into the ground water at the facility.
- A discussion of upset conditions that may have occurred during any sampling events or laboratory analysis that may influence the results.
- Assessment of the QA/QC program effectiveness.
- A summary of investigation results (including tables that summarize analytical results).
- References identifying prior site investigation reports and other supporting information.
- Appendices containing relevant data, supporting information, and other documents.

2. Based on a review of the components and information contained in this GWRFI Report, the requirements for an RFI and the DTSC Corrective Action Consent Agreement have been met. In addition, characterization issues raised by the DTSC in an April 1999 meeting with LMC have also been addressed in this GWRFI. These issues included ground water mounding and defining the lateral and vertical extent of ground water impacts.